FOSSIL WOOD FROM SOUTH GEORGIA

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ABSTRACT. Although fossils are rare in the Cumberland Bay Formation, South Georgia, petrified wood is common throughout the sequence. By careful sectioning and examination, some of this material has been classified within a broad group system and has yielded potentially useful stratigraphical information.

SOUTH GEORGIA comprises elements of an island-arc–back-arc basin system that was active from the Jurassic until the mid-Cretaceous (Dalziel and others, 1975). Most of the island is made up of the Cumberland Bay Formation (Fig. 1): a thick deformed sequence of turbidites. Although fossils are rare, this formation seems to be mainly early Cretaceous in age (Thomson and others, in press). The turbidites were derived from the island arc and are mainly andesitic volcaniclastic greywackes (Winn, 1978; Tanner and others, 1981). The rocks of the turbidite basin are separated from the island-arc terrain and its basement by a major high angle fault (Tanner, in press). There is a second turbidite unit, the Sandebugten Formation, which is pre-

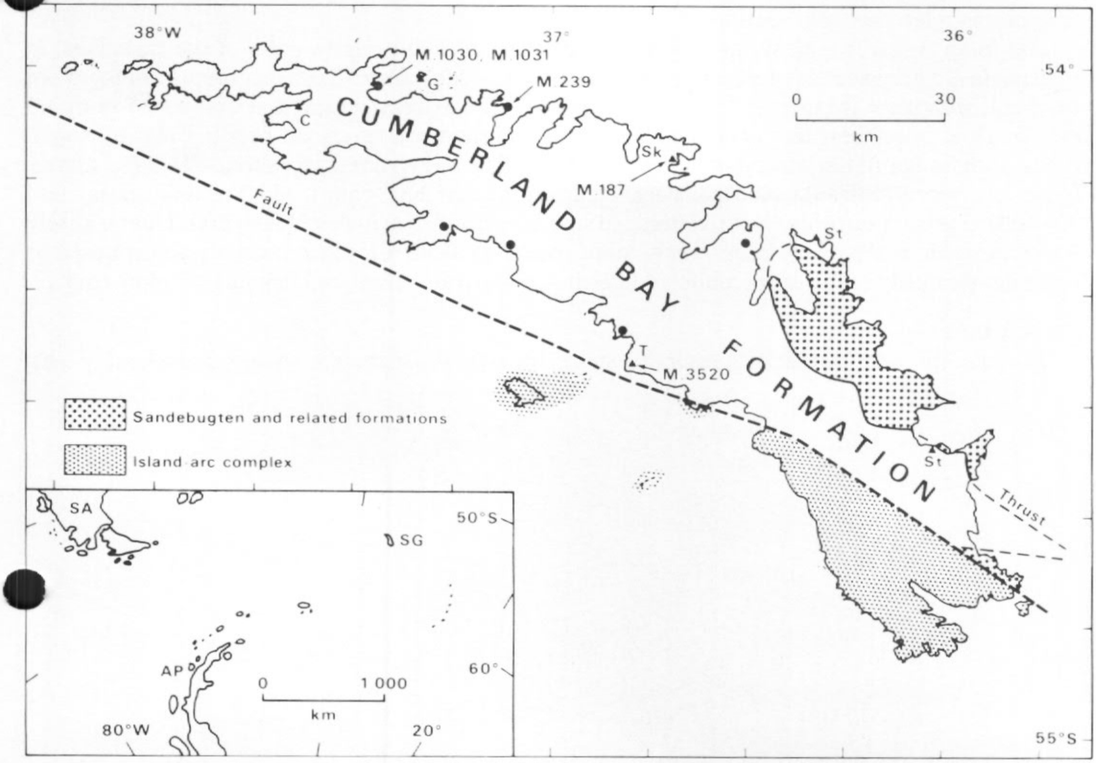

Fig. 1. Simplified geological sketch map of South Georgia, showing fossil wood localities. The inset map shows the location of South Georgia (SG) in relation to South America (SA) and the Antarctic Peninsula (AP). Locations of specimens of fossil wood described in this paper are indicated by arrows and station numbers. Solid triangles indicate published fossil wood localities (G, Gordon, 1930; Sk, Skidmore, 1972; St, Stone, 1975; C, Clayton, 1976; T, Tanner and others, 1981, solid circles indicate unpublished fossil wood localities (data from British Antarctic Survey archives).

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dominantly formed of silicic detritus, and was probably derived from the continental side of the back-arc basin (Winn, 1978). The two turbidite formations are probably of equivalent age, but the Cumberland Bay Formation is thrust over the Sandebugten Formation (Tanner, in press).

During early Cretaceous times, South Georgia is thought to have been at a palaeolatitude of 55° to 60° S (Smith and others, 1981) and palaeocurrent evidence suggests that much of the wood was derived from a source further to the south-east, probably from the active island-arc terrain (Macdonald and Tanner, in prep.). The palaeoclimatic problems of tree growth in Cretaceous polar regions are beyond the scope of this paper, but will be discussed in a forthcoming paper on early Cretaceous fossil wood from a palaeolatitude of 70°S (Jefferson, in prep.).

FOSSIL WOOD

Occurrence

Fragments of fossil wood have been found throughout the Cumberland Bay Formation, and have been commented on by a number of authors (Gordon, 1930; Skidmore, 1972; Stone, 1975; Clayton, 1976; Tanner and others, 1981). Stone (1975) also found carbonized wood fragments in the Sandebugten Formation. All known fossil wood localities are shown in Fig. 1. All collected material in the possession of the British Antarctic Survey was re-examined, and suitable samples were thin-sectioned.

The fossil wood fragments are found within the top of the sandy units of the turbidites, in volcaniclastic greywackes of medium sand grade. They vary in size from less than 1 cm to 15 cm by 5 cm, with most fragments being 5–10 cm long. The extreme example found was 4 m by 60 cm. In hand specimen, the wood appears as thin carbonized layers on bedding planes, sometimes with longitudinal striations visible (Fig. 2). The greywackes comprise 20–30% matrix (generally recrystallized), 40–70% rock fragments (including chloritized volcanic glass) and 10–40% crystal fragments (mostly albitized and sericitized plagioclase feldspars). Quartz rarely forms more than 5% of the rock. The Cumberland Bay Formation has been metamorphosed to prehnite–pumpellyite facies; prehnite and calcite are patchily developed throughout most rocks.

Preservation

The quality and mode of preservation of the wood fragments varies considerably. All

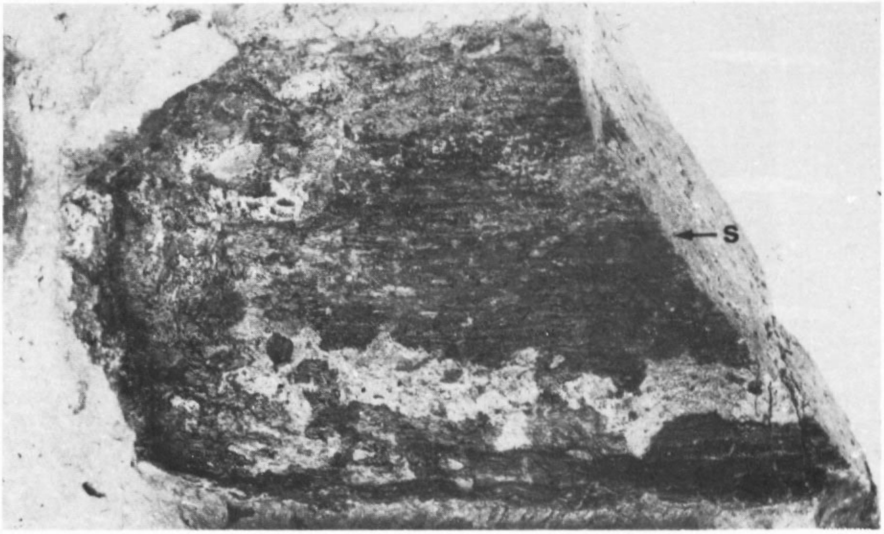


Fig. 2. Specimen of fossil wood, showing longitudinal striations (s) which represent the long axes of tracheids; × 1 (M.187.3a).

specimens are partly carbonized, particularly at their outer margins, and some specimens are wholly carbonized. Carbonized areas result from cells which decayed, collapsed and were compacted before any mineralization could take place. Products of this decay often contaminated the surrounding sediment with residual organic material, forming an orange-brown halo. In some cases, the released organic acids caused leaching of iron minerals up to 1 cm from the margins of the fragments, forming a pale "reaction-halo" with a dark brown rim.

The tracheid cells, which run longitudinally in a woody plant stem, lie parallel to the long axes of the fragments, but have been rotated and dissociated. This is particularly noticeable in specimen M.3520.3, where there are disorganized groups of up to 17 cells (Fig. 3a–c) containing tracheids and medullary rays (cells radiating from stem centres). Since permineralization would have cemented cells together via pits between them, disorganization must have taken place before petrification. One of the first processes in the decay of wood is the breakdown of the

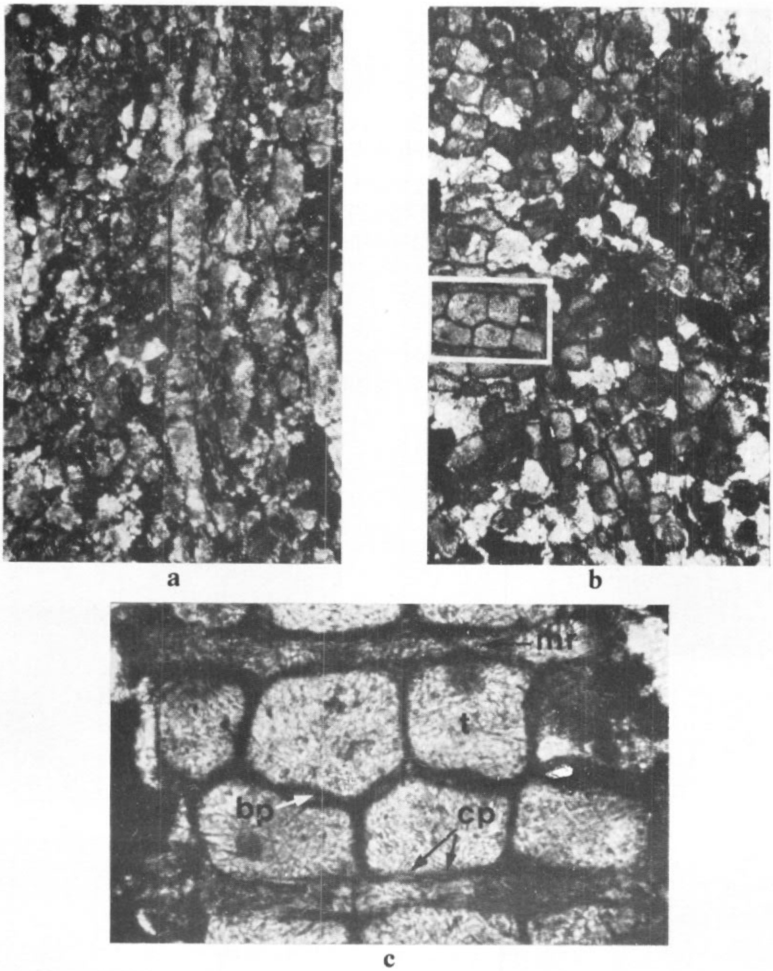


Fig. 3. Photomicrographs of silicified wood (M.3520.3).
- a. Radial longitudinal section, showing disorganization of cells; × 100.
- b. Transverse section, showing dissociated cells and groups of cells with prehnite crystals (white areas) between them; × 100.
- c. Transverse section (enlargement of enclosed area in b), showing tracheids (t), medullary rays (mr), bordered pits (bp) and ? cross-field pits (cp); × 400.

middle lamellae by fungi (Kaarik, 1974), and it may be the removal of this layer, which is common to adjacent cells, that leads to dissociation. This decay must have occurred before the wood was totally waterlogged, and thus isolated from oxygen, and must have been arrested before burial, otherwise the cells would be totally dissociated.

In specimen M.3520.3, most cells are permineralized by silica, which occurs as anhedral quartz crystals growing into cell lumens from cell walls, as radiating needles of quartz growing from cell centres, or in an amorphous hydrated form. More than one quartz crystal occupies each cell, but these do not penetrate cell walls. Buurman (1972) described this type of fill as polyblastic. A few cells are preserved in chlorite, which has a spongy texture and is discoloured by (?) organic material. In rare cases, prehnite is present, but only where the cell wall is ruptured. Anhedral prehnite fills most of the cavities between cells and cell groups. These cavities also contain rare mineral fragments from the sediment matrix which may have provided the nucleation points necessary for the crystallization of prehnite, whereas, inside cells, such points are absent. A more important control on mineralization is the potential within the cells for hydrogen bonding between ligno-holocellulosic complexes of the cell wall and silicic acid (H_2SiO_3). This favours the precipitation of silica (Leo and Barghoorn, 1976), preserves fine cellular details that are lost in other forms of petrification, and is less likely to disrupt cell walls.

Specimens M.187.3a and M.187.3b show little disorganization and their cells are still arranged in files, but their structure is less well preserved (Fig. 4a, b). The cell walls are irregular in thickness, often have diffuse outlines, and no longer show any fine detail. The cells are infilled by prehnite, chlorite and quartz in approximately equal proportions, with radiating crystals growing through cell walls, filling several adjacent cells in optical continuity. This is hyperblastic fill (Buurman, 1972). The matrix of the sediment has penetrated the fragments in many places, usually between cells, but in a few cases it has invaded the cells. This relatively poor preservation is probably due to advanced pre-petrifaction decay which may have broken down cell walls and allowed disruptive growth of prehnite within cells (Fig. 5a, b).

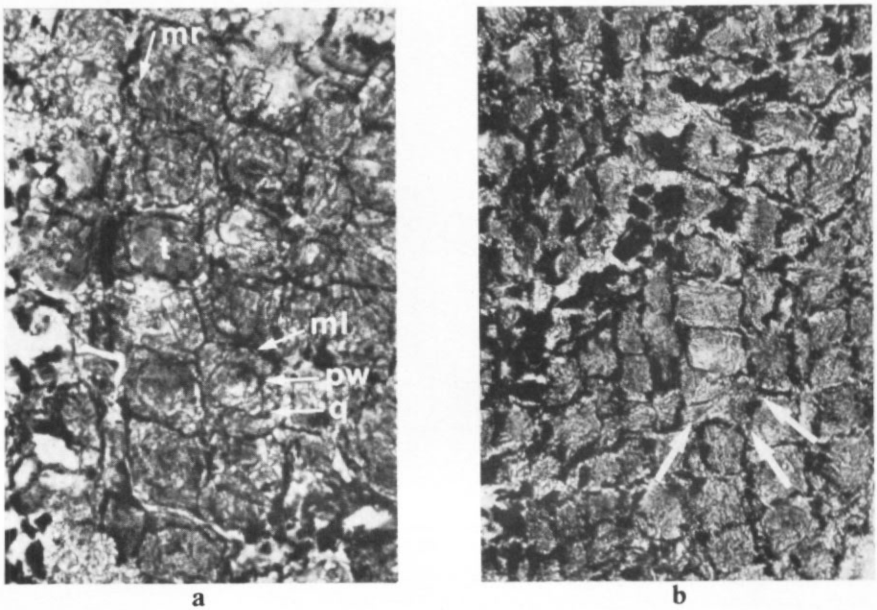


Fig. 4. Transverse sections through tracheids (t) and medullary rays (mr).
a. Showing growth of quartz (q) between the middle lamella (ml) and primary cell wall (pw); × 400 (M.187.3a).
b. Disruption of cell walls by prehnite crystals (indicated by arrows); × 250 (M.187.3b).

In all the relatively well-preserved examples there are areas of poorer preservation where a mosaic of prehnite is found associated with a random network of organic material. In specimens M.239.1, M.1030.1, M.1030.2 and M.1031.18, this is the only type of preservation found.

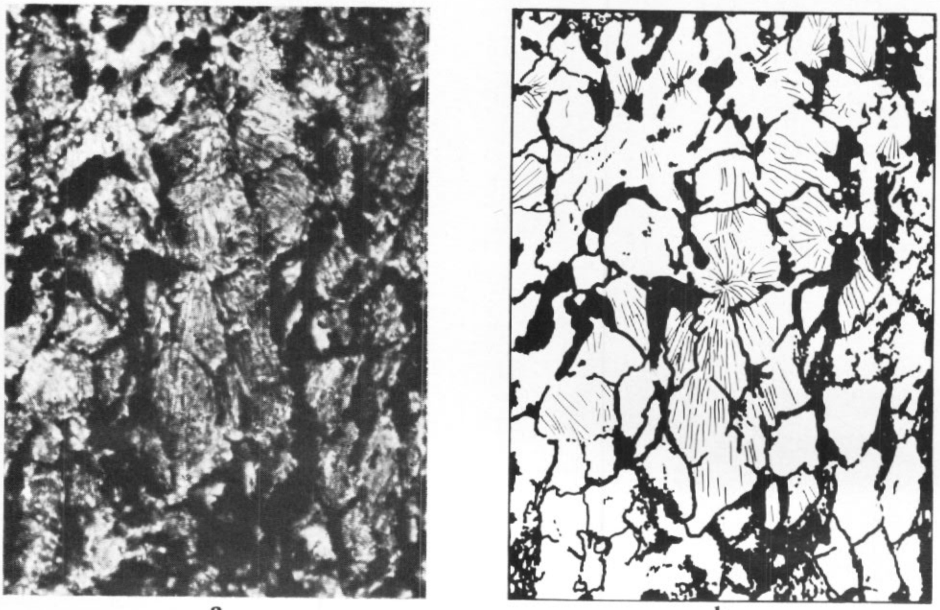
It seems that the state of decay of the wood during petrifaction determines the relative importance of the two stages in the mineralization process, and that this gives rise to a wide range in the quality of cell preservation.

The earliest stage involves silica and chlorite, probably formed diagenetically by the breakdown of volcanic glass and feldspar (Murata, 1940; Sigleo, 1979). Leo and Barghoorn (1976) suggested that permineralization of wood by silica always begins in the amorphous form, and that transformation into a thermodynamically stable crystalline state takes place gradually. Buurman (1972) considered that both amorphous and crystalline forms can be primary, under different pore fluid pressures and silica concentrations. In the examples discussed here, the shape of the crystals and their interference patterns in the centre of the cells supports this view.

The second stage of preservation is marked by the growth of prehnite which is present in all specimens. In the best-preserved examples this is restricted to spaces outside cells (Fig. 3a–c), probably because the cells were permineralized at an early stage. In other specimens, prehnite occurs within cells, which it seems to disrupt, in inverse proportion to the amount of silica and/or chlorite present (Figs 4b, 5a). Prehnite has been observed exerting disruptive pressure on host minerals (Moore, 1976), though this is not always the case (Tulloch, 1979). It is therefore probable that advanced decay permitted invasive and disruptive prehnite growth in specimens where early mineralization had not occurred.

Taxonomy

The only specimen of fossil wood previously reported from the Cumberland Bay Formation was described as *Dadoxylon (Araucarioxylon)* on the basis of its biseriate bordered pits on



a b

Fig. 5. Cell disruption by radiating prehnite needles (M.187.6).
a. Photomicrograph of transverse section; × 400.
b. Drawing of (a). Thick lines represent disrupted cell walls and cell wall material, fine lines represent outlines of prehnite needles, many of which penetrate cell walls.

tracheid radial walls, uniseriate (or at most biseriate) medullary rays and equidimensional pith cells (Gordon, 1930). All the fossil wood fragments from new localities (see Fig. 1) were coniferous secondary wood consisting of tracheids and medullary rays (Figs 3c, 4a). There is no evidence of parenchyma cells or resin ducts, no area of cells large enough for the recognition of growth rings is preserved, and pith cells occur in only one specimen. Because specimens are only 1–2 mm thick and are not uniformly preserved it is not possible to make radial and tangential longitudinal sections which were adequate for determining cross-field pitting or the height of medullary rays.

Four specimens are sufficiently well preserved to merit further description:

Specimen M.3520.3. Tracheids are 25–50 μm (radial) by 19–41 μm (tangential), at least 0.6 mm long and are polygonal, usually pentagonal, in cross-section. Bordered pits, up to 30 μm in diameter, on radial walls of the tracheids usually have a separate uniseriate arrangement (Fig. 6a) but may be biseriate and contiguous. Medullary rays are uniseriate up to 10 μm across, and appear to bear several cross-field pits per tracheid (Fig. 3c). Re-orientation of cells further hindered the preparation of longitudinal sections.

Specimen M.187.3a consists of an outer zone, 0.03 mm thick, of regular files of tracheids an[illegible] poorly preserved central area up to 0.12 mm across, which contains small areas of round equidimensional cells (Fig. 7a, b). These probably represent pith but lack any cellular detail. Tracheids are 19–20 μm (radial) by 10–13 μm (tangential), at least 0.8 mm long and usually rectangular in cross-section. Uniseriate bordered pits on radial walls are circular, 23 μm in diameter and

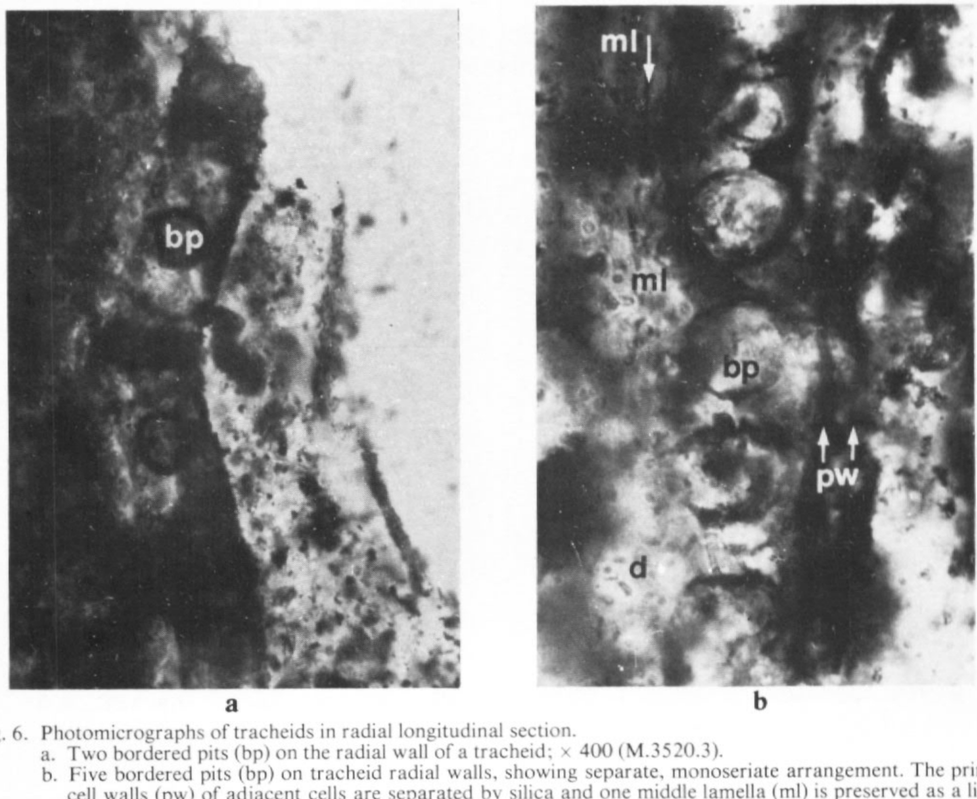


Fig. 6. Photomicrographs of tracheids in radial longitudinal section.
a. Two bordered pits (bp) on the radial wall of a tracheid; × 400 (M.3520.3).
b. Five bordered pits (bp) on tracheid radial walls, showing separate, monoseriate arrangement. The primary cell walls (pw) of adjacent cells are separated by silica and one middle lamella (ml) is preserved as a line of carbon inclusions; part of the cell wall decayed before mineralization (d); × 1000 (M.187.3a).

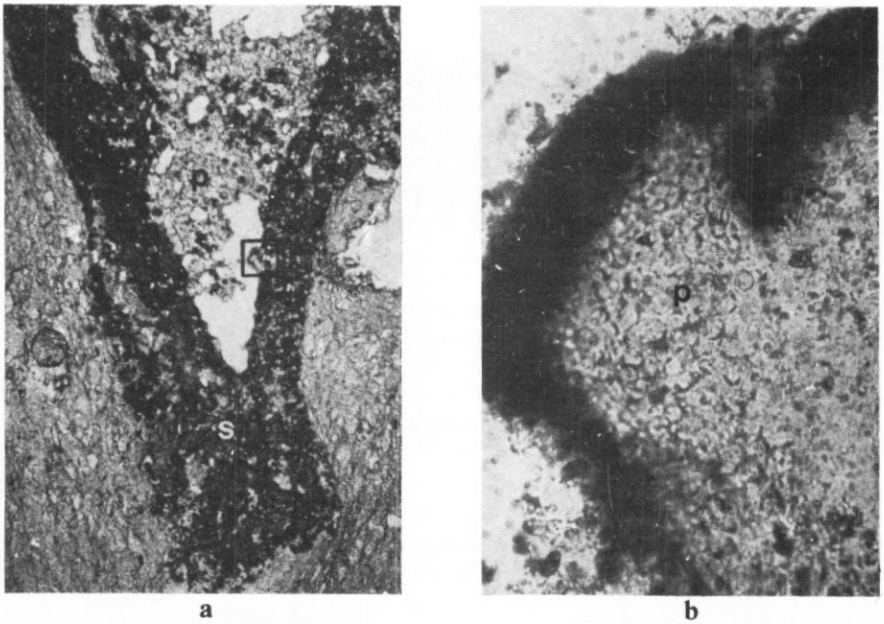


Fig. 7. Photomicrographs of fossil wood in transverse section (M.187.3a).
a. Outer zone of secondary wood (s) with poorly preserved central zone of pith cells (p); × 25.
b. Enlargement of enclosed area in (a), showing poorly preserved pith cells (p); × 400.

dominantly separate (Fig. 6b). Medullary rays are uniseriate, 7.5–12.5 μm across and at least 5 cells in height.

The growth of quartz and prehnite between the primary cell walls of adjacent cells often enables the middle lamella to be recognized as a line of carbon inclusions (Fig. 6b).

Specimen M.187.3b. Tracheids are rectangular in cross-section and 20–23 μm (radial) by 10–12.5 μm (tangential) (Fig. 4b). Medullary rays are 7 μm across and uniseriate. Tracheid pitting is probably uniseriate but this has not been confirmed by radial sectioning.

Specimen M.187.6. Rectangular tracheids 23–25 μm (radial) by 9–13 μm (tangential) and at least 1 mm long, bear round bordered pits. These are 18 μm in diameter and have a uniseriate, separate arrangement on radial walls. Medullary rays are uniseriate and 8 μm across.

Exquisite preservation of medullary rays and cross-field pitting is necessary to utilize most of identification keys published for fossil conifer wood (e.g. Kräusel, 1949). Since the preservation of the South Georgia wood is not of this quality the more general "group system" proposed by Creber (1972) must be used here. All the fragments, in which tracheid pitting was seen, fall within Group B. This is characterized by a virtual absence of resin dusts, and circular and normally separate bordered pits on radial walls of tracheids. Group B comprises the genera *Cedroxylon, Cupressinoxylon* and *Mesembrioxylon* and their later subdivisions, but excludes the genus *Dadoxylon.*

CONCLUSIONS

An understanding of the state of preservation of fossil wood can provide useful information about sediment diagenesis, since the timing and mineralogy of petrifaction is determined by post-depositional processes within the matrix. It can also help in assessing the significance of orientated fragments as palaeocurrent indicators (Macdonald and Jefferson, in prep.).

Although the taxonomic information from poorly preserved fossil wood is of little use in detailed stratigraphy, the proportions of each wood group in an assemblage have been used in geological correlation (Creber, 1972). Detailed examination of fragments of wood from South Georgia has enabled many specimens to be classified within this broad group system and all fall into Group B. Assemblages strongly dominated by fossil woods of Group B are characteristic of Jurassic–Cretaceous sequences. Creber (1972) suggested that the similarity of assemblages from the Middle Kimmeridgian and Volgian of the British Jurassic (both dominated by Group B) might prove to be a valuable stratigraphic tool, and more extensive collection and examination of wood fragments from the Cumberland Bay Formation may enable a more detailed stratigraphic correlation in the future.

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